

# Palynomorph assemblages in a hemipelagic succession as indicators of transgressive-regressive cycles: Example from the Upper Turonian of the Bohemian Cretaceous Basin, Czech Republic

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**Abstract:** Palynomorph assemblages from a hemipelagic succession of the Teplice Formation (Upper Turonian) exposed in the Úpohlavy quarry were analyzed for species occurrence and abundance. Environmental interpretations based on these data were compared with lithological and geochemical data, as well as with regional genetic stratigraphy. This comparison suggests that (a) palynomorph assemblages with high marine/non-marine ratios, and dominance of dinoflagellates over other marine palynomorphs, characterize the hemipelagic intervals of maximum flooding; (b) late regressive and early transgressive systems tracts are characterized by low marine/non-marine ratios and a relatively high abundance of acritarchs and prasinophytes at the expense of dinoflagellates; (c) relatively high species abundance of both marine and non-marine palynomorphs is associated with the most shore-proximal hemipelagic setting; the increased species abundance of marine taxa in this setting was probably related to elevated input of land-derived nutrients during the peak regression. In general, this confirms that changes in palynomorph assemblages can be sensitive indicators of changes in terrigenous clastic and nutrient input into the hemipelagic environment. Palynomorph assemblages thus provide valuable criteria for recognition of key genetic stratigraphic surfaces and systems tracts in hemipelagic settings; in such depositional systems lithological criteria alone can be misleading due to the complicating effects of relative sea-level-independent variations in productivity of skeletal plankton.

**Keywords:** Palynomorphs, Genetic Stratigraphy, Cretaceous, Turonian, Bohemia, Hemipelagic

## 1. INTRODUCTION

This paper illustrates the relationships between palynomorph spectra and genetic stratigraphy in a distal, hemipelagic succession, based on combined palynological, sedimentological, and geochemical research in the Teplice Formation (Upper Turonian) of the Bohemian Cretaceous Basin (Czech Republic; Fig. 1).

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Lithology of hemipelagic facies is sensitive to changes in input of terrigenous mud and to variations in productivity of skeletal plankton. The input of terrigenous sediment into distal portions of sedimentary basins is closely linked to climate, tectonic processes in the source areas, and, importantly, to relative sea level (RSL). In contrast, the relationships of productivity of skeletal plankton to RSL and terrigenous input are less straightforward. For example, EICHER & DINER (1989) argue that the classic hemipelagic rhythms of the Bridge Creek Limestone of the Western Interior Basin were triggered solely by circulation-driven variations in pelagic productivity and do not show any evidence for accompanying changes in terrigenous dilution.

Therefore, in hemipelagic deposits the combination of changes in terrigenous dilution and productivity of skeletal plankton can make it difficult to distinguish the effects of RSL fluctuations. This study examines the sensitivity of the palynological record of a hemipelagic system to transgressive and regressive episodes, which may have occurred in tandem with RSL changes. Studies of palynomorph assemblages in the context of sequence stratigraphy have been conducted previously, for example by HABIB et al. (1992) and MONTEIL (1993). Our approach is based on comparing the results of palynological analysis from an outcrop section of the hemipelagic facies with results obtained by detailed subsurface correlation to coeval, RSL-sensitive clastic strata of a coarse-grained, deltaic depositional system.

## 2. MATERIAL AND METHODS

Palynological samples were prepared with standard techniques (HCl, HF treatment, sieving of residues using a 10  $\mu\text{m}$  sieve, mounting on glycerine-jelly) at the laboratory of the Czech Geological Survey, Prague. The slides containing the illustrated specimens are stored in the collections of the Institute of Geology, Academy of Sciences of the Czech Republic, Prague. The positions of the samples in the studied section are indicated in Fig. 2.

In the palynological samples, abundance of specimens in the individual palynomorph groups, species abundance, and ratios of marine/continental palynomorphs were assessed. The palynological data were integrated with petrological and geochemical data, and compared with the regional stratigraphy of the depositional system (see below; Figs. 1 and 2). Detailed descriptions of lithofacies,  $\text{CaCO}_3$  and organic carbon contents, can be found in ČECH et al. (1996).

Detailed sequence stratigraphic interpretation of the hemipelagic succession will be discussed in a future paper. Due to space limitations, this paper also does not discuss in detail the lowest orders of recognizable stratigraphic cyclicity (marl-limestone couplets and their bundles). Even though a minimum of three orders of stratigraphic cyclicity is present in the studied succession, this paper focuses on recognition and palynological evaluation of relatively high-order stratigraphic cyclicity (3<sup>rd</sup> or upper 4<sup>th</sup> order *sensu* MIALL, 1990; the time span represented by the Úpohlavy section is probably less than 700 ky based on biostratigraphic data of ČECH et al., 1996, and absolute dating of coeval strata by OBRADOVICH, 1993).

Because of difficulties with definition and correlation of sequence boundaries *sensu* VAN WAGONER et al. (1988) in the studied settings (see ULIČNÝ, 2001, in press), the stratigraphic framework used in this paper is based on recognition of regionally correl-



ative surfaces of maximum flooding. These surfaces subdivide the stratigraphic succession into stratigraphic units, which are equivalent to the genetic stratigraphic sequences of GALLOWAY (1989). Each of the genetic sequences is further subdivided into regressive and transgressive systems tracts (*sensu* HELLAND-HANSEN & MARTINSEN, 1996). Geometric stacking of the individual genetic sequences defines the highest order of stratigraphic cyclicity discussed in this paper. Although the following discussion is based on the interpretative genetic stratigraphy, for descriptive purposes a reference is made also to the local lithostratigraphic scheme applied by ČECH et al. (1996; Fig. 1b here).

### 3. RESULTS

#### 3.1. Sedimentology and regional stratigraphy – description

The Úpohlavý quarry is located in the western part of the Bohemian Cretaceous Basin, which, during the Late Turonian, was characterized by relatively quiet depositional conditions and sedimentation dominated by hemipelagic facies (ČECH et al., 1996) beyond the progradational limits of coarse-grained deltas sourced from uplifted areas northeast (Fig. 1a). Good regional subsurface (well-log) control allows correlation of individual parts of the hemipelagic succession with coeval deltaic packages (Fig. 1c). The pelagic to hemipelagic succession studied at Úpohlavý is characterized by irregular, decimeter-scale alternations of relatively carbonate-rich and carbonate-poor beds (Fig. 1b). Limestone textures range from planktonic foraminiferal packstones to wackestones (ČECH et al.,

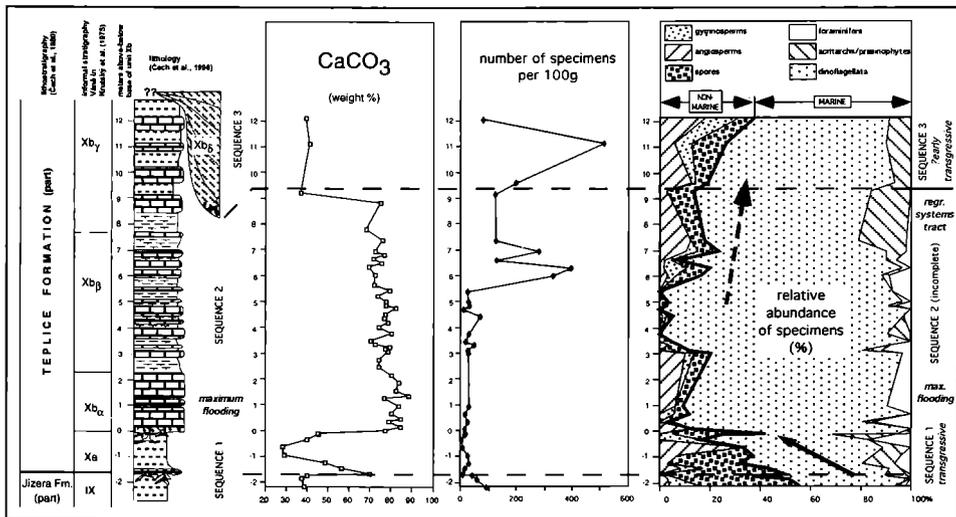


Fig. 2: Lithology, calcium carbonate contents, palynomorph abundances, and composition of the palynomorph assemblages of the Úpohlavý section; dashed lines mark boundaries of medium-scale lithological packages; comments in text; for explanation of the lithological symbols see Fig. 1b.

1996). The local lithostratigraphic units Xa and Xb $\alpha$ , as defined by ČECH et al., 1996 (see Fig. 1b), display sharp lower contacts – local to regional omission surfaces – which are covered by winnowed skeletal and lithoclast accumulations. A local scour showing erosional relief of up to 7.5 meters is found at the base of unit Xb $\delta$  in the area of the Úpohlavý quarry (Fig. 1b), paved in its deepest parts by a phosphatic conglomerate. The rest of the scour-fill is formed by silicified, poorly bioturbated marlstones to calcareous mudstones (Fig. 1b).

Apart from the small-scale lithological variations outlined above, higher-order lithological changes of several scales are present in both outcrops and well logs (Figs. 1 and 2). The highest order of variation is represented by the overall upward decrease in carbonate contents, with a minimum in the scour-fill of unit Xb $\delta$ .

### 3.2. Sedimentological interpretation of relative sea-level history

A series of regional proximal-distal transects (example on Fig. 1c) revealed the temporal relationships of the hemipelagic succession of the Úpohlavý area to complexes of sandy, shoal-water deltas in the northern part of the basin. Three major genetic sequences *sensu* GALLOWAY (1989) can be distinguished in these siliciclastic deposits (here informally labelled as sequences 1 to 3; Fig. 1c) based on recognition of regionally extensive flooding surfaces. Sequences 1 and 2 are stacked in a larger-scale progradational pattern. Sequence 3 backsteps relative to the underlying sequence 2 in this part of the basin (Fig. 1c). However, it is important to note that sequence 3 is generally coarser-grained than the underlying sequences, which may seem to be in contradiction to its backstepping nature, in generalized sequence-stratigraphic models associated with a RSL rise (e.g. VAN WAGONER et al., 1988) or a decrease in sediment supply.

The hemipelagic succession of Úpohlavý onlaps onto the regressive to lower transgressive systems tracts of sequence 1 (Fig. 1c). Hemipelagic deposition continued during the formation of sequences 2 and 3.

As shown on Figs. 1a and 1c, the clastic-dominated and hemipelagic depositional systems form two distinct depocenters separated by an approximately NW-trending uplifted zone, which probably coincided with a part of the Elbe fault zone. Episodic faulting along this zone during the deposition of sequences 1 to 3 is documented by onlapping geometries of both the clastic-dominated and hemipelagic strata along the zone (Fig. 1c). No comparable geometries are found in the underlying, distal, but mud-dominated, deposits. This suggests that tectonic partitioning of the accommodation space caused trapping of clastics to the north of the faulted zone and, at the same time, an increase in depth in the distal region to the south. Thus, localized fault-controlled subsidence might have been the dominant factor enabling the long-term coexistence of the clastic-dominated and hemipelagic depositional systems. Further, a coeval increase in subsidence rate and sediment input in the proximal area may have led to the above-mentioned “misfit” between the backstepping arrangement of sequences 2 and 3, and the overall coarsening-upward trend.

In the genetic stratigraphic interpretation presented here, using also the regional proximal-distal correlations (see Fig. 1c), the part of the Jizera Formation exposed at Úpohlavý probably represents the latest part of the regressive systems tract of sequence 1. The phosphatic omission surface at the base of unit Xa is interpreted as the surface of

maximum regression *sensu* HELLAND-HANSEN & MARTINSEN (1996). Unit Xa of the Teplice Formation represents the early transgressive systems tract of sequence 1. The base of unit Xb $\alpha$  marks the onset of a rapid shoreline retreat, and the base of the zone of maximum flooding in the hemipelagic setting; its approximate correlative level in the clastic-dominated system is the boundary between genetic sequences 1 and 2.

Unit Xb $\beta$  probably represents the regressive portion of genetic sequence 2. Peak regression of sequence 2 was probably contemporaneous with deposition of the mudstone bed beneath limestone Xb<sub>14</sub>. Incompleteness of the stratigraphic record prevented a detailed assessment of the genetic relationship of the scour fill found at Úpohlavý to the clastic-dominated system. Rough correlation suggests that it corresponds to a part of sequence 3 (Fig. 1c). Based on petrographic indices, ULIČNÝ and LAURIN in ČECH et al. (1996) proposed that the basal scoured surface represents a tectonically accentuated regressive surface of marine erosion, possibly equivalent to a sequence boundary *sensu* VAN WAGONER et al. (1988). If so, the scour-fill could be considered a peak regressive or early transgressive systems tract of sequence 3 (using the concept of HELLAND-HANSEN & MARTINSEN, 1996). Erosional structures similar to the scour fill at Úpohlavý have been described from the Anglo-Paris Basin (e.g. JARVIS, 1992), and, interestingly, their occurrence was interpreted to coincide with long-term episodes of low RSL (see JARVIS, 1992).

### 3.3. Palynology

The following section describes changes in palynomorph assemblages recorded in the Úpohlavý section (Fig. 2). The most significant events and trends were recognized in the internal composition of dinoflagellate cyst and spore-pollen assemblages, and in the stratigraphic distribution of triporate angiosperm pollen and dinoflagellate cyst species.

#### 3.3.1. Jizera Formation

##### peak regression of sequence 1

The grey calcareous mudstones of the Jizera Formation yielded a mixed assemblage of miospores and dinoflagellate cysts. Among the spores which are common and diverse in this interval (they form 40% of the assemblage), the most abundant are *Cicatricosisporites venustus*, *Cicatricosisporites* sp. (family Schizeaceae), *Camarozonosporites insignis* (family Lycopodiaceae), *Dictyophyllidites harrisii*, *Gleicheniidites senonicus*, and *Gleicheniidites carinatus* (family Gleicheniaceae). Among the gymnosperm pollen, bisaccates are relatively abundant (namely *Parvisaccites radiatus*) and also some halophyte pollen of the family Cheirolepidiaceae – *Classopollis classoides* is present. Dinoflagellate cysts include mostly long-ranging forms such as *Achomosphaera ramulifera*, *Cleistosphaeridium* cf. *perforoconum*, *Microdinium ornatum*, *Canningia colliveri*, *Chlamydophorella ambigua* a.o. This interval is characterized by the dominance and low diversity of microplankton taxa with the prevalence of gonyaulacean taxa. Rare angiosperm triporate pollen from the Normapolles group, mostly *Trudopollis* sp. and *Complexiopollis* sp., occur. Compared to the overlying strata, the uppermost part of the Jizera Formation shows a relatively high proportion of terrestrial elements.

Dinoflagellate cysts	seour fill	METERS ABOVE/BELOW THE BASE OF TEPLICE FM.																								
		9.2	7.4	7.0	6.65	6.35	6.05	5.75	5.45	5.15	4.9	4.5	3.8	3.5	3.4	3.15	3.05	1.0	0.7	0.4	-1.2	-1.65	-1.8	-2.1		
<i>Acanthaulax wilsonii</i>	*																									
<i>Achomosphaera ramulifera</i>	+	+		+		+	A	A				*						*			+	+		+	+	
<i>Achomosphaera triangulata</i>	*	*																								
<i>Alterbidinium daveyi</i>																									*	
<i>Aptodinium</i> sp.		*																								
<i>Canmingia</i> sp.												+	+	+								+		*		
<i>Chatangiella diuissima</i>	+	A																								
<i>Chatangiella spectabilis</i>		+																								
<i>Chatangiella</i> spp.	+	A	+		+			+	*																	
<i>Chlamydothorea ambigua</i>	+	+	+	+			A	A	A	+	+	+	*	+		+	+		+			+				
<i>Chlamydothorea discreta</i>	+	+								+	+	+														
<i>Chlamydothorea nyei</i>								+	+					+		+										
<i>Cleistosphaeridium armatum</i>	+			+	*													*								
<i>Cleistosphaeridium perforoconum</i>																										
<i>Coronifera oceanica</i>	+	+				*			*																	+
<i>Craspedinium turonicum</i>									+																	
<i>Cribrerodinium</i> cf. <i>cooksoniae</i>						*			*																	
<i>Circulodinium distinctum</i>									+			+														
<i>Cylonephelinum compactum</i>		*							*																	
<i>Diconodinium</i> sp.	*	*																								
<i>Dinogymnium</i> cf. <i>albertii</i>		*																								
<i>Dinogymnium</i> sp.		*															*									
<i>Dinopterignum cladosides</i>		*																								
<i>Disphaeria macropylla</i>									+																	
<i>Endoscrinium campalum</i>		+							*																	
<i>Exochosphaeridium bifidum</i>	+	+							*	*		+	+	+		+										+
<i>Florentinia deamei</i>	*	*							*	*																
<i>Florentinia ferox</i>		*		*			*	*																		
<i>Florentinia mantellii</i>		*		*	*																					
<i>Hystriochosphaeropsis gateata</i>		*																								
<i>Hystriochodinium pulchrum</i>									*																	
<i>Hystriochostrogylon membraniphorum</i>		+				*																				
<i>Isabelidinium cretaceum</i>									+																	
<i>Isabelidinium</i> spp.	+	+	+			+		+	*																	+
<i>Leberidocysta chlamydata</i>	+	+							*																	
<i>Microdinium ornatum</i>	*	*						*					+													*
<i>Microdinium veligerum</i>	*	*						*																		+
<i>Microdinium setosum</i>								*																		
<i>Odontochitina costata</i>																			*							
<i>Odontochitina operculata</i>	+	*				*	A			*	*					*	*									
<i>Oligosphaeridium complex</i>	+	*			+		+	+	+						+	+	+									
<i>Palaeohystriochophora infusorioides</i>	*	+																								
<i>Palaeoperidinium cretaceum</i>						*			*																	
<i>Pervosphaeridium truncigerum</i>		*							+																	
<i>Pterodinium cingulatum</i>		*																								
<i>Rhipiocorys veligera</i>																										*
<i>Spiniferites ramosus</i>	+	A			+		+		A				+		+	+	+									
<i>Spiniferites reticularis</i>		+																								
<i>Stephodinium coronatum</i>	+	*				+			*																	
<i>Subtilisphaera</i> sp.	+	+	+			*	+		*						+											
<i>Surculosphaeridium longifurcatum</i>	+	+	+				+																			
<i>Tanyosphaeridium</i> sp.	*	*							*	*																
<i>Trichodinium castaneum</i>	+	*		*					+																	
<i>Xenascus ceratioides</i>	+			*		*	+	+		A																
<i>Xenascus</i> cf. <i>gochti</i>		*																								
SPECIES ABUNDANCE	20	38	10	5	6	9	10	13	27	2	4	4	3	5	1	5	8	3	2	2	3	3	1	3	3	6
GENETIC STRATIGRAPHY	?early TST	regressive systems tract																	maximum flooding						early TST	
	SEQ. 3	SEQ. 2																	I	SEQ. 1						

Tab. 1: Distribution of dinoflagellate cyst taxa in the Úpohlavý section. The samples are identified by their position above/below the base of the Teplice Fm. (see Fig. 2). Explanation of symbols: \* present (0–5 specimens), + common (6–10 specimens), A abundant (more than 11 specimens); SEQ. – genetic stratigraphic sequence *sensu* GALLOWAY (1989); TST – transgressive systems tract *sensu* HELLAND-HANSEN & MARTINSEN (1996).

Acritarchs and prasinophytes	scour fill		METERS ABOVE/BELOW THE BASE OF TEPLICE FM.																						
			9.2	7.4	7.0	6.65	6.35	6.05	5.45	5.05	4.9	4.5	3.8	3.5	3.4	3.15	3.05	1.0	0.7	0.4	-1.2	-1.65	-1.8	-2.1	
<i>Cymatiosphaera costata</i>		*																							
<i>Fromea amphora</i>		*																							
<i>Fromea fragilis</i>	*		*										*												
<i>Leiofusa jurassica</i>				+		*																			
<i>Leiosphaeridia</i> spp.			*																						
<i>Michhystridium</i> spp.	*						*			*	*			*					*		*	*	*	*	*
<i>Pterospermella aureolata</i>			*																						
<i>Pterospermella australiensis</i>	*		*	*	*	*															*	*	*	*	*
<i>Veryhachium reductum</i>	*	*	*	*	+		*							*											
<i>Wallodinium humum</i>																					*				
Miscellaneous																									
scolecodons			*																						
SPECIES ABUNDANCE	4	4	5	3	3	0	2	0	0	0	1	1	0	1	2	0	0	0	0	0	1	1	3	2	2
GENETIC STRATIGRAPHY	?early TST		regressive systems tract														maximum flooding					early TST			
	SEQ. 3		SEQ. 2														SEQ. 1								

Tab. 2: Distribution of acritarchs and prasinophytes in the Úpohlavý section; see captions of Tab. 1 for explanation of symbols.

Spores	scour fill	METERS ABOVE/BELOW THE BASE OF TEPLICE FM.																							
		9.2	7.4	7.0	6.5	6.5	6.05	5.45	5.05	4.9	4.5	3.8	3.5	3.4	3.15	3.05	1.0	0.7	0.4	-1.2	-1.55	-1.8	-2.1		
<i>Appendicisporites</i> sp.	*																								
<i>Camazonosporites insignis</i>																						*	*	*	
<i>Cicatricosisporites venustus</i>							*	*											*	*	*	*	*	*	
<i>Cicatricosisporites</i> cf. <i>subrotundus</i>																					*	*	*	*	
<i>Cicatricosisporites</i> sp.																									
<i>Cingutirletes</i> sp.	*							*																	
<i>Clavifera triplex</i>	+		*					*																	
<i>Cyathidites australis</i>	*	*	*																					*	
<i>Deloidospora minor</i>	*	*	*					*															*	*	
<i>Dictyophyllidites</i> sp.	+			*				*															*	*	
<i>Echinatisporis varispinosus</i>				*	*	*	*	*																*	
<i>Gleicheniidites carinatus</i>																								*	
<i>Gleicheniidites senonicus</i>	A	*	*	*	*	*	+	+			*				*	*			*	*	*	*	*	*	
<i>Leiotriletes</i> sp.			*																					*	
<i>Retitriletes austroclavatidites</i>	*																							*	
<i>Sestrosporites</i> sp.	*																							*	
<i>Stereosporites antiquasporites</i>	*																							*	
<i>Toroisporis</i> sp.																							*	*	
<i>Trilites</i> sp.				*																				*	
<i>Vadaszsporites urkuticus</i>							*																	*	
<b>Gymnosperm pollen</b>																									
<i>Alisporites bialteralis</i>	+																								
<i>Classopollis classoides</i>	A																								
<i>Cycadopites fragilis</i>	*																								
<i>Parvisaccites radianus</i>																								*	
<i>Pinuspollenites</i> sp.	A																							*	
<i>Taxodiaceapollenites hiatus</i>	*																							*	
<i>Vitreosporites pallidus</i>	*																							*	
<b>Angiosperm pollen</b>																									
<i>Complexipollis</i> sp.			*	*	*	*		+						*	*	*	*	*	*	*	*	*	*	*	
<i>Plicapollis</i> sp. A	*							*																*	
<i>Plicapollis seria</i>	*																							*	
<i>Pseudoplicapollis</i> sp.	*	*	*	*	*	*																		*	
<i>Retitricolporites</i> sp.	*		*			*																		*	
<i>Trudopollis imperfectus</i>	*					*																		*	
<i>Trudopollis</i> cf. <i>nonperfectus</i>	*																							*	
<i>Trudopollis</i> sp.	+					*		*											*	*	*	*	*	*	
<i>Vacuipollis</i> sp.		*	*	*	*	*	*	*																*	
Normapollis undeterm.	+	*	*	*	*	*	*	*			*										*	*	*	*	
<b>SPECIES ABUNDANCE</b>	1	23	5	7	5	4	2	9	9	1	0	0	1	1	0	0	2	1	1	1	2	4	2	4	11
<b>GENETIC STRATIGRAPHY</b>	?early TST	regressive systems tract														maximum flooding				early TST					
	SEQ. 3	SEQ. 2														SEQ. 1									

Tab. 3: Distribution of terrestrial palynomorphs in the Úpohlavý section; see captions of Tab.1 for explanation of symbols.

### 3.3.2. Teplice Formation – Units Xa through Xby

*transgressive systems tract of sequence 1 to regressive systems tract of sequence 2*

The lowermost part of the Teplice Formation, Xa, is characterized by a stepwise increase in relative abundance of marine plankton at the expense of terrestrial elements, which is then followed by an abrupt shift towards dominance of marine palynomorphs at the base of unit Xb $\alpha$ . The lower part of the transgressive systems tract of sequence 1 (100 cm above the base of the Teplice Fm.; Fig. 2) is characterized by the appearance of ceratioid dinoflagellate cysts, *Odontochitina operculata* and *Odontochitina costata*, chitinous linings of microforaminifers and some acritarchs (*Micrhystridium* sp., *Veryhachium reductum*), rare prasinophytes, i.e. *Pterospermella australiensis*, *Tasmanites* sp.

Some new triporate angiosperm Normapolles taxa, *Plicapollis*, *Pseudoplicapollis*, *Vacuopollis*, appear 305 cm above the base of the Teplice Fm. Among the dinoflagellate cyst taxa recorded from this interval are *Chlamydothorella nyei*, *Chlamydothorella ambigua*, *Chlamydothorella discreta*, *Spiniferites ramosus*, *Exochosphaeridium bifidum*. More abundant and diverse microplankton associations are recorded in the 605–700 cm interval (see Tab.1).

First occurrences of the cavate cysts *Chatangiella* and *Isabelidium* and also rare *Dinogymnium* specimens are recorded in this part of the section. The first occurrence of the genus *Chatangiella* in the Bohemian Cretaceous thus predates the first occurrence of this genus in the Bavarian Cretaceous (Coniacian, according to KIRSCH, 1991; Dr. Julianne Fechner, pers. comm., 2000). According to the biostratigraphic data in ČECH et al. (1996), this part of the Úpohlavy section belongs to the Late Turonian nannofossil Zone CC13B.

### 3.3.3. Teplice Formation – scour-fill, unit Xb $\delta$

?early transgressive part of sequence 3

The scour-filling deposits of this part of sequence 3 have a slightly higher marine/continental ratio than the regressive deposits of sequence 2 (Fig. 2). Significantly, the microplankton taxa are more diverse, acritarch/prasinophyte specimens are more abundant and individual specimens are larger. *Isabelidium*, *Chatangiella*, *Dinogymnium* are more numerous and diverse. A diverse assemblage of dinoflagellate cysts includes *Xenascus ceratioides*, *Xenascus gochtii*, *Odontochitina operculata*, *Florentinia ferox*, *Florentinia deanei*, *Stephodinium coronatum*, *Endoscrinium campanulum* and rare *Cribroperidinium edwardsii*. Acritarchs (*Veryhachium reductum*, *Veryhachium hyalodermum*, *Micrhystridium* spp., *Fromea amphora*) and prasinophyte algae (*Pterospermella helios*, *Pterospermella* cf. *aureolata* and *Tasmanites* sp.) are more common relative to the underlying deposits.

The miospore assemblage consists mainly of pteridophyte spores referable to the genera *Gleicheniidites*, *Clavifera*, *Echinatisporites*, *Cicatricosisporites* and *Cyathidites*, and extremely rare gymnosperm pollen referable to *Classopollis/Corollina* pollen (halophyte pollen of the family Cheirolepidiaceae). Triporate angiosperm pollen consist mainly of the genera *Trudopollis*, *Plicapollis* and *Pseudoplicapollis*.

#### 4. DISCUSSION

Abundances of palynomorph species seem to correlate partly with the total number of specimens (Tables 1 to 3; Fig. 2). This feature may be due to insufficient size of the relatively poor samples. On the other hand, no significant systematic relationship appears to exist between the relative abundances of specimens in individual palynomorph groups and the total number of specimens (Fig. 2). The relative abundances of marine/non-marine palynomorph taxa correlate, at a large scale, with the geochemical and lithological data (Fig. 2). Theoretically, this correlation may point to lithology-related preservational bias. However, the coincidence of high marine/non-marine ratios and the carbonate-rich beds contradicts our expectations from biased palynological record: non-marine taxa (namely strongly ornamented spores and triporate angiosperm pollen from the *Normapolles* group) have relatively high preservation potential compared to dinoflagellates and other marine palynomorphs (e.g. ŽITŤ et al., 1997). We therefore assume that lithology-related preservational limits were not the major control on the observed palynomorph spectra. The relative abundances of specimens in individual palynomorph groups (Fig. 2) are assumed to provide a relatively robust database for further discussion.

The major features emerging from the integration of the basic palynological data with the genetic stratigraphy outlined above include:

- (1) The peak regressive to early transgressive parts of sequences 1 and 3 correspond to the minima in marine/non-marine palynomorph ratios; these stratigraphic intervals also appear to be characterized by relatively high abundances of acritarchs and prasinophytes at the expense of dinoflagellates (Fig. 2);
- (2) a stepwise increase in the marine/non-marine ratio occurs between the peak regression of sequence 1 and the onset of maximum flooding of this sequence;
- (3) the broad zone of maximum flooding between sequences 1 and 2 represents maxima in both marine/non-marine ratios and the relative abundance of dinoflagellates.

The changes in marine/non-marine ratios appear to correlate with the genetic stratigraphic framework at the scale of individual systems tracts, suggesting a strong link between this palynological parameter and the terrigenous input. The reciprocal changes in abundances of acritarchs/prasinophytes and dinoflagellates probably reflect trophic exclusion (cf. PRAUSS, 1989). The increased relative abundance of acritarchs and prasinophytes, and corresponding relative decrease in abundance of dinoflagellates in the late regressive to early transgressive systems tracts (Fig. 2), suggests ecological preference of acritarchs and prasinophytes for the relatively shallow parts of the depositional setting. Similar relationships were observed in oxygen-deficient environments (e.g. PIASECKI & STEMMERIK, 1991), but further geochemical and ichnological research is necessary to assess the actual environmental parameters responsible for these trophic changes in the Úpohlavý setting.

Anomalous palynomorph assemblages are found in the scour fill (sequence 3). Firstly, this part of the succession shows a high species abundance of both marine and non-marine palynomorph groups, compared to the samples from the upper part of sequence 2. Secondly, it is characterized by the dominance of ceratioid cysts of *Chatangiella* spp., a high species abundance of other dinocysts, and relatively large sizes of the dinocysts and acritarchs (Pl. II). These features suggest that a nutrient-rich, slightly restricted (possibly low-salinity) marine environment prevailed during deposition of the scour-fill facies (cf.

BUJAK, 1984, RIDING et al., 1991). The acritarch genus *Fromea* has been interpreted by SCHRANK & MAHMOUD (1998) to be indicative of stressed environmental conditions, possibly due to reduced salinity. The high species abundance of marine palynomorphs (namely dinoflagellates) in the scour fill at Úpohlavý is probably due to interaction of open-marine and continental influences, and resulting diversification of nutrient resources in the relatively shore-proximal hemipelagic setting (cf. HABIB et al., 1994: 327).

The palynological results are generally consistent with the geometry and facies of the coeval shoreface (Fig. 1c). Based on these observations we suggest that the composition of palynomorph assemblages can provide sensitive information on changes in terrigenous input into a hemipelagic environment and can thus be used as a valuable tool in genetic stratigraphic analysis in hemipelagic settings.

## 5. CONCLUSIONS

Palynomorph assemblages of the hemipelagic succession of the Úpohlavý quarry recorded palaeoenvironmental changes related to variations in input of land-derived sediment and nutrients. Although these processes are not exclusively tied to changes in relative sea level, the integration of palynology and sedimentology may provide a powerful tool for genetic stratigraphic analysis of hemipelagic settings.

Our results suggest that in the Úpohlavý quarry

(1) palynomorph assemblages with high marine/non-marine ratios, and dominance of dinoflagellates over other marine palynomorphs, characterize the hemipelagic intervals of maximum flooding;

(2) late regressive and early transgressive systems tracts are characterized by low marine/non-marine ratios and relatively high abundances of acritarchs and prasinophytes at the expense of dinoflagellates;

(3) relatively high species abundances of both marine and non-marine palynomorphs are associated with the most shore-proximal hemipelagic setting; the increased species abundance of marine taxa in this setting was probably related to elevated input of land-derived nutrients during the peak regression.

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## Plate 1

The individual samples are identified by their position above/below the base of the Teplice Formation (see Fig. 2). All micrographs  $\times 1000$ .

Fig. 1: *Camarozonosporites insignis* NORRIS 1967, Jizera Formation., slide 981/3, depth – 165 cm

Fig. 2: *Cicatricosporites venustus* DEAK, Teplice Fm., 1002/2, 505 cm

Fig. 3: *Cyathidites australis* COUPER 1963, Jizera Fm., 979/3, -210 cm

Fig. 4: *Cicatricosporites* sp., Jizera Fm., 979/2, -210 cm

Fig. 5: *Retitricolporites* sp., Teplice Fm., 996/1

Fig. 6: *Plicapollis sarta* PFLUG 1953, Teplice Fm., 994/1, 305 cm

Fig. 7: *Complexiopollis* sp., Teplice Fm., 993/1, 100 cm

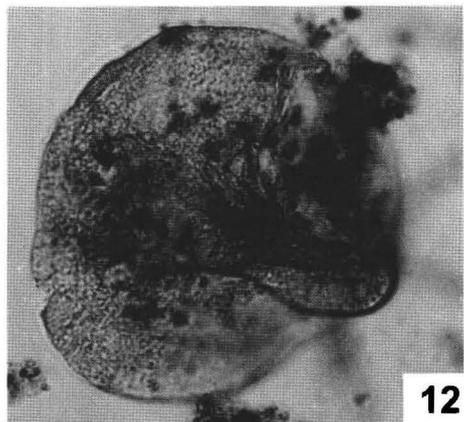
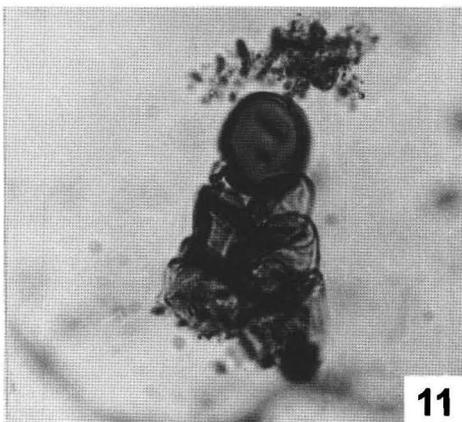
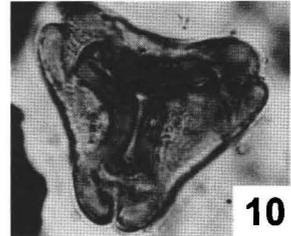
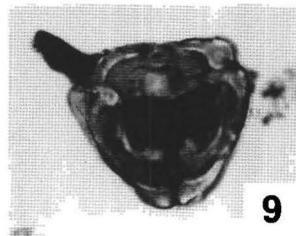
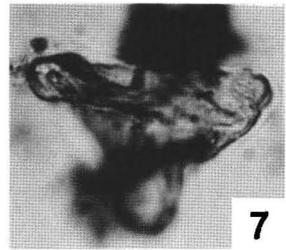
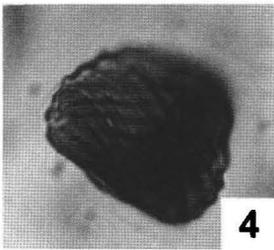
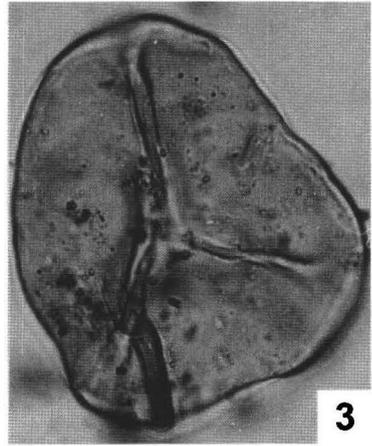
Fig. 8: *Trudopollis* cf. *nonperfectus* PFLUG 1953 Teplice Fm.- scour fill, C5/55, 1049/5

Fig. 9: *Trudopollis imperfectus* PFLUG 1953 Teplice Fm. – scour fill, C5/55

Fig. 10: *Plicapollis* sp. A, Teplice Fm. – scour fill, C5/55

Fig. 11: chitinous linings of microforaminifers – biserial, Teplice Fm., 993/1, 100 cm

Fig. 12: *Parvisaccites radiatus* COUPER, Jizera Fm., 979/1, -210 cm



## Plate 2

The individual samples are identified by their position above/below the base of the Teplice Formation (see Fig. 2). All micrographs × 1000.

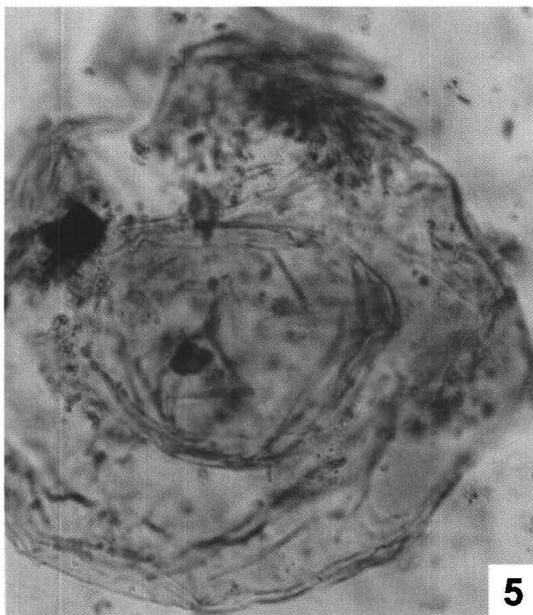
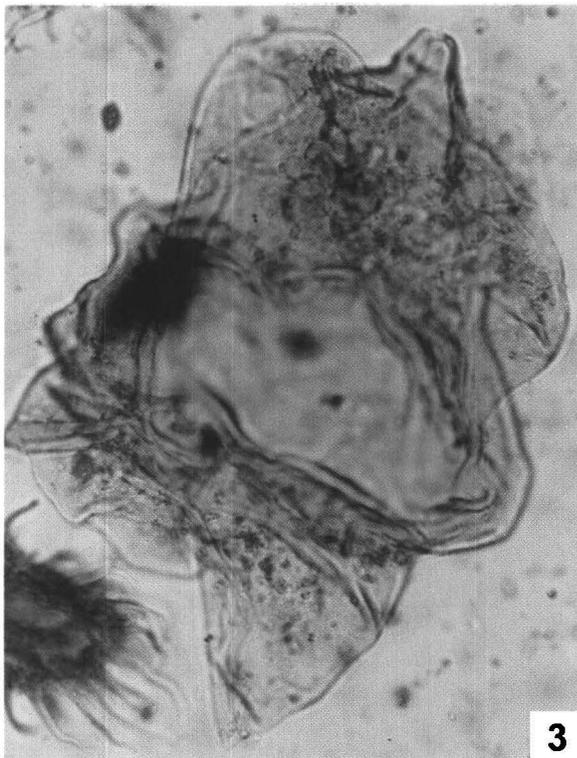
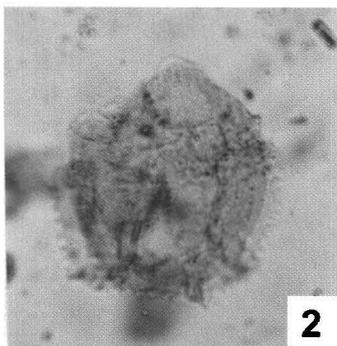
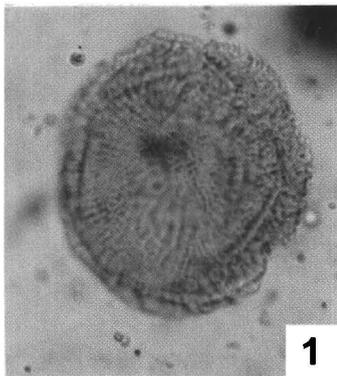
Fig. 1: *Chlamydothorella discreta* CLARKE & VERDIER, Teplice Fm., 1048/2, 605 cm

Fig. 2: *Microdinium setosum* SARJEANT, Teplice Fm., scour fill- C5/55, 1049/5

Fig. 3: *Chatangiella tripartita* (COOKSON & EISENACK 1960a) LENTIN & WILLIAMS 1976, Teplice Fm., scour fill- C5/55, 1041/1

Fig. 4: *Chatangiella ditissima* (MCINTYRE 1975) LENTIN & WILLIAMS 1976, Teplice Fm., scour fill- C5/55, 1049/2

Fig. 5: *Disphaeria macropyla* COOKSON & EISENACK 1960a, Teplice Fm., 1048/2, 605 cm



### Plate 3

The individual samples are identified by their position above/below the base of the Teplice Formation (see Fig. 2).

Fig. 1: *Chatangiella* cf. *ditissima* (MCINTYRE 1975) Lentin & Williams 1976, Teplice Fm. – scour fill, C5/55, SEM × 2000.

Fig. 2: *Cymatiosphaera costata* Teplice Fm. – scour fill, C5/55, SEM, × 4000.

Fig. 3: *Veryhachium reductum* DEUNFF 1958, Teplice Fm. – scour fill, C5/55, SEM, × 4000.

Fig. 4: *Chatangiella* sp., Teplice Fm. – scour fill, C5/55, SEM × 1500.

